Carbonate clumped isotope thermometry of the Notch Peak contact metamorphic aureole

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Carbonate 'clumped' isotope thermometry has been widely used to reconstruct climate, altitude, vertebrate body temperatures, and other low temperature phenomena, but few studies have explored its behaviour in higher temperature diagenetic and (particularly) metamorphic environments. Here we report the results of an investigation of the apparent temperatures recorded by clumped isotope compositions in coexisting calcite and dolomite in marbles from the Notch Peak contact aureole, UT. Here, flat-lying upper Cambrian limestones were intruded by a Jurassic quartz monzonite pluton, producing marbles that decrease in peak metamorphic grade with increasing distance from the pluton.

Apparent temperatures for calcite are never greater than ~150˚C, even in portions of the aureole that saw peak metamorphic conditions in excess of 500 ˚C. This result cannot be reconciled with experimental constraints on rates of isotopic re-ordering in calcite unless the background temperature (i.e., long after the intrusion cooled) was close to this measured value. E.g., a background temperature even 25 degrees lower should have led to preservation of apparent temperatures of 200+ ˚C. When this model result is combined with structural constraints on the depth of the analysed strata (6 km, prior to exhumation by Tertiary block faulting), it implies a geothermal gradient of 20-22 ˚C/Km between the Jurassic and Tertiary.

Apparent temperatures for dolomite from outside the metamorphic aureole are also on the order of 150 ˚C, but jump sharply higher to ~300 ˚C throughout the region within 2 km of the intrusion. This is consistent with dolomite having exceeded and then cooled back through a blocking temperature of 300 °C within the aureole, and recording background diagenetic/burial metamorphic conditions (either before or after pluton intrusion) at greater distances. Thus, the 'jump' in dolomite apparent temperatures documents the location of the ~300 ˚C isotherm associated with intrusion. We are currently conducting laboratory studies of the kinetics of reordering in dolomite so that these data can be interpreted in more detail as constraints on temperature-time history.

Fractionations of C and O isotopes between calcite and dolomite exhibit a remarkably consistent relationship to distance to the intrusion and clumped isotope temperatures, which can be interpreted as a reflection of differences in blocking temperatures between the homogeneous clumped isotope equilibria and the heterogeneous isotope exchange equilibria.